



INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

USA

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation and Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein together with the Statement of inventorship and of right to grant of a Patent (Form 7/77), which was subsequently filed.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Stephen Hordley

Dated 19 February 2004

THIS PAGE BLANK (USPTO)

Patents Form 1/77

Patents Act 1977
(Rule 16)

29 APR 2003

The
Patent
OfficeTHE PATENT OFFICE
JR

29 APR 2003

RECEIVED BY FAX

177
29 APR 2003 003521-1002319
F01/7700 0.00-0309750.8

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH**Request for grant of a patent***(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)*

1. Your reference

CM05224EI/DJM/GBRI/LCC/CORSE

2. Patent application number

(The Patent Office will fill in this part)

0309750.8

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*MOTOROLA, INC
1303 EAST ALGONQUIN ROAD,
SCHAUMBURG, ILLINOIS 60196,
U.S.A.Patents ADP number *(if you know it)*~~00284407004~~

08488371001

If the applicant is a corporate body, give the country/state of its incorporation

U.S.A.

DELAWARE

4. Title of the invention

WIRELESS COMMUNICATION TERMINAL AND VOLTAGE CONTROLLED
OSCILLATOR THEREFOR5. Name of your agent *(if you have one)**"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)*DEREK J MCCORMACK
EUROPEAN INTELLECTUAL PROPERTY DEPARTMENT
MIDPOINT
ALENCON LINK
BASINGSTOKE
HAMPSHIRE RG21 7PL
UK
ADP NO. 00001180006

7957749001

Patents ADP number *(if you know it)*6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country

Priority application number
*(if you know it)*Date of filing
(day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing
*(day / month / year)*8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*☒ YES ☐ NO*a) any applicant named in part 3 is not an inventor, or**b) there is an inventor who is not named as an applicant, or**c) any named applicant is a corporate body.**See note (d))*

Patents Form 1/77

0067499 29 Apr 03 02:39

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description	19
Claim(s)	4
Abstract	1
Drawing(s)	4

1st pr

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (Patents Form 7/77)	4
--	---

Request for preliminary examination and search (Patents Form 9/77)	1
--	---

Request for substantive examination (Patents Form 10/77)	1
--	---

Any other documents (please specify)	1 x FEE SHEET
--------------------------------------	---------------

pr

11.

I/We request the grant of a patent on the basis of this application.

Signature

Derek J McCormack

Date

29/4/03

12. Name and daytime telephone number of person to contact in the United Kingdom

DEREK J MCCORMACK

Louise CRISTOFOLI

01256 790589

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

- If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.
- Write your answers in capital letters using black ink or you may type them.
- If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.
- If you have answered 'Yes' Patents Form 7/77 will need to be filed.
- Once you have filled in the form you must remember to sign and date it.
- For details of the fee and ways to pay please contact the Patent Office.

Patents Form 7/77

Patents Act 1977
(Rule 15)

29 APR 2003

The
Patent
OfficePATENT OFFICE
JR

29 APR 2003

RECEIVED BY FAX

7/77

Statement of inventorship and of
right to grant of a patent

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference **CM05224EI/DJM/GBRI/LCC/CORSE**
2. Patent application number
(if you know it) **0309750.8**
3. Full name of the or of each applicant **MOTOROLA, INC**
1303 EAST ALGONQUIN ROAD,
SCHAUMBURG, ILLINOIS 60196,
U.S.A.
4. Title of the invention **WIRELESS COMMUNICATION TERMINAL AND VOLTAGE
CONTROLLED OSCILLATOR THEREFOR**
5. State how the applicant(s) derived the right
from the inventor(s) to be granted a patent
**THE APPLICANT IS ENTITLED TO THE INVENTION BY VIRTUE OF THE INVENTOR(S)
EMPLOYMENT**
6. How many, if any, additional Patents Forms
7/77 are attached to this form?
(see note (c))
7. I/We believe that the person(s) named over the page (and on
any extra copies of this form) is/are the inventor(s) of the invention
which the above patent application relates to.
- | | |
|--------------------------|----------------|
| Signature | Date |
| DEREK J MCCORMACK | 29/4/03 |
8. Name and daytime telephone number of
person to contact in the United Kingdom **Louise CRISTOFOLI** **01256 790589**

Notes

- a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.
- b) Write your answers in capital letters using black ink or you may type them.
- c) If there are more than three inventors, please write the names and addresses of the other inventors on the back of another Patents Form 7/77 and attach it to this form.
- d) When an application does not declare any priority, or declares priority from an earlier UK application, you must provide enough copies of this form so that the Patent Office can send one to each inventor who is not an applicant.
- e) Once you have filled in the form you must remember to sign and date it.

Patents Form 7/77

0067499 29-Apr-03 02:39

Patents Form 7/77

Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

CORSE, NIR

MOTOROLA ISRAEL LTD.
3 KREMENETSKY STREET
TEL AVIV 67899
ISRAEL

8488389001

Patents ADP number (if you know it):

NIR, SHAY

MOTOROLA ISRAEL LTD.
3 KREMENETSKY STREET
TEL AVIV 67899
ISRAEL

8621294001

Patents ADP number (if you know it):

ROZENTAL, MARK

MOTOROLA ISRAEL LTD.
3 KREMENETSKY STREET
TEL AVIV 67899
ISRAEL

8481228001

Patents ADP number (if you know it):

Reminder

Have you signed the form?

Patents Form 7/77

0067499 29-Apr-03 02:39

WIRELESS COMMUNICATION TERMINAL AND VOLTAGE CONTROLLED
OSCILLATOR THEREFOR

Field of the Invention

5

This invention relates to a wireless communication terminal and a voltage controlled oscillator therefor. The invention is applicable to, but not limited to, a voltage controlled oscillator (VCO) for generating radio frequencies across a wide frequency range and/or over a number of distinct frequency bands.

1 0

Background of the Invention

1 5 Wireless subscriber communication units, for example those operating in a cellular telephone system such as the Global System for Mobile communications (GSM) or operating on a private mobile radio system such as a Terrestrial Trunked Radio (TETRA) communication system, use oscillator circuits to generate the radio frequency signals.

2 0

An oscillator circuit has two primary functions:

(i) An active device, such as a transistor, to produce power gain; and

2 5

(ii) A feedback network, routing a sufficient amount of the active device's output signal to an input of the active device, to sustain oscillations. In effect, the component values of the feedback network

3 0

determine the operating frequency. The circuit oscillates when the product of the transistor gain times the network losses (including any mismatches) substantially equals '1'. In practice, the product is

CM05224EI/DM/GB/Corse

- 2 -

set to a value slightly higher than '1' so that oscillations can start and build up to a high level.

5 A common oscillator implementation is known as a voltage controlled oscillator (VCO) circuit, where an input tuning voltage is applied to an oscillator circuit and the tuning voltage adjusted to set the frequency at which the circuit oscillates. The frequency range of the VCO circuit is limited to circuit component parameters and
1 0 the tuning voltage used.

Note that a narrow band VCO circuit is typically defined as:

$$(F_{\max} - F_{\min}) / F_{\text{average}} < 10\% \text{ of } F_c$$

1 5 That is, a narrowband VCO is typically considered to have an acceptable frequency range of less than ten percent of its nominal oscillating frequency.

2 0 However, the widespread adoption of wireless technologies has created a need to allocate frequency spectrum in separate frequency bands to accommodate all potential users of that communication technology. For example, GSM spectrum has been allocated in both the 800 MHz frequency band as well as the 900 MHz frequency band. In addition,
2 5 TETRA has been allocated frequency spectrum in the 380-400 MHz frequency band, as well as the 410-430 MHz frequency band.

3 0 Thus, to avoid manufacturing different wireless subscriber communication units (terminals) for different frequency bands, wireless subscriber unit manufacturers need to develop wireless subscriber communication units capable of operating over a wider frequency range. In this manner, a single wireless subscriber communication

CM05224EI/DM/GB/Corse

- 3 -

unit is then able to encompass all potential frequencies supported by the respective communication standard.

5 One option to support a wide frequency range within a single wireless subscriber communication unit is to design two separate VCO circuits.

1 0 An alternative approach would be to provide a wideband voltage controlled oscillator (VCO). Developing a single wideband VCO to operate across the desired frequency range saves cost and space, when compared to the alternative solution of designing two separate VCO circuits.

1 5 However, the implementation of a 'wideband' VCO is more complex. Furthermore, the inventors of the present invention have recognised that a significant disadvantage with such wideband VCO designs is that VCO phase noise degrades over the frequency band. This problem is
2 0 exacerbated as the VCO bandwidth increases. Increasing the VCO tuning bandwidth, particularly over say 10% of its centre frequency, has noticeably increased this effect in a traditional Colpitts VCO configuration. This effect is noticeable irrespective of the VCO component
2 5 values used.

3 0 In the known Colpitts VCO design, for the sole purpose of tuning the VCO frequency is typically shifted using a single variable capacitor. Occasionally, two variable capacitors may be used, again for the sole purpose of tuning the VCO frequency. It can be shown that increasing a VCO frequency range will increase the amount of capacitance change in the VCO using the variable

CM05224EI/DM/GB/Corae

- 4 -

capacitor. The increased capacitance change will increase the variable capacitance losses as well.

5 Generally, any attempt to improve a loaded-Q performance at high tuning voltages results in a lower gain margin at low tuning voltages. This, in turn, leads to oscillation start up problems, particularly in a traditional Colpitts VCO configuration.

1 0 Thus, there exists a need to provide a wireless communication unit that can operate over a wide frequency range. In particular, there exists a need for an improved VCO design to maintain low phase noise across the wide frequency range.

1 5

Summary of Invention

In accordance with a first aspect of the present invention, there is provided a wireless communication
2 0 terminal. The wireless communication terminal comprises a voltage controlled oscillator having an active device, for producing a power gain, operably coupled to a main variable capacitance, whose capacitance varies according to a voltage applied to a steering line. A feedback
2 5 network, comprising a resonator, is operably coupled to an output of the active device for feeding power back to an input of the active device to sustain oscillations. Notably, a second variable capacitance is also operably coupled to the steering line voltage and located adjacent
3 0 to the resonator.

~~In accordance with a second aspect of the present invention there is provided a voltage controlled~~

CM05224EI/DM/GB/Corse

- 5 -

oscillator circuit for use in the wireless communication terminal.

5 The provision of an additional (second), variable, tuning capacitance, located adjacent to the resonator enables a VCO to operate over a wider bandwidth with the same tuning voltages, say around 15% of the VCO's centre frequency. This is achieved, effectively, due to the use of gain margin tuning applied to the resonator and second
1 0 variable capacitor of the VCO circuit. In particular, the provision of an additional (second) variable capacitor located adjacent to the resonator provides an increase in loaded-Q at high tuning voltages, i.e. it provides better phase noise at those frequencies. It
1 5 also provides an increase in gain margin at low frequencies, i.e. it insures a minimum gain margin to provide sufficient oscillation, thereby providing greater start-up confidence at low tuning voltages. In this manner, the present invention solves the problem of lack,
2 0 of gain margin in a traditional Colpitts VCO configuration that would have resulted in oscillation start-up problems in the lower tuning voltage range.

2 5 Further features of the present invention are defined in the dependent Claims.

Exemplary embodiments of the present invention will now be described, with reference to the accompanying drawings, in which:

3 0

Brief Description of the Drawings

CM05224EI/DM/GB/Corse

- 6 -

FIG. 1 illustrates a block diagram of a wireless communication unit adapted to support the various inventive concepts of the present invention;

5 FIG. 2 shows a graph illustrating a VCO loop gain analysis in small signal mode;

FIG. 3 shows a graph illustrating a VCO loop gain analysis in a steady state (large signal) mode; and

1 0

FIG. 4 illustrates a Colpitts VCO configuration adapted to support the various inventive concepts of the present invention.

1 5 Description of Embodiments of the Invention

A block diagram of a wireless subscriber communication unit (often termed mobile station (MS)) 100 is shown in FIG. 1. The MS 100 is adapted to support the inventive
2 0 concepts of the preferred embodiments of the present invention. The MS 100 contains an antenna 102 preferably coupled to a duplex filter or antenna switch 104 that provides isolation between receive and transmit chains within the MS 100.

2 5

The receiver chain includes receiver front-end circuitry 106 (effectively providing reception, amplification and filtering of the received signal). The received signal is input to a frequency conversion circuit 128 that
3 0 receives a reference oscillator signal from the frequency generation circuit 123. The frequency conversion circuit 128 preferably comprises mixing and amplifier elements (not shown), as known in the art. The frequency conversion circuit 128 is serially coupled to a signal

CM05224EI/DM/GB/Corse

- 7 -

processing function (generally realised by a digital signal processor (DSP)) 108 via a baseband (back-end) processing circuit 107.

- 5 A controller 114 is operably coupled to the frequency generation circuit 123 and/or frequency conversion circuit 128. A received signal strength indication (RSSI) function 112 provides receive bit-error-rate (BER) calculations, or frame-error-rate (FER) calculations or
1 0 similar link-quality measurement data to the processor 108. The RSSI function 112 is operably coupled to the front-end circuit 106. A memory device 116 stores a wide array of MS-specific data, for example decoding/encoding functions, frequency and timing information for the
1 5 communication unit, etc. A timer 118 is operably coupled to the controller 114 to control the timing of operations, namely the transmission or reception of time-dependent signals, within the MS 100. As known in the art, received signals that are processed by the signal
2 0 processing function are typically input to an output device 110, such as a speaker or visual display unit (VDU).

- The transmit chain essentially includes an input device
2 5 120, such as a microphone, coupled in series through a processor 108, transmitter/modulation circuitry 122, frequency generation/conversion circuit 128 and a power amplifier 124. The processor 108, transmitter/modulation circuitry 122 and the power amplifier 124 are
3 0 operationally responsive to the controller. An output from the power amplifier is coupled to the duplex filter or antenna switch 104, as known in the art.

CM05224EI/DM/GB/Corse

- 8 -

In accordance with a preferred embodiment of the present invention, the radio frequency generation circuit 123, which is a voltage controlled oscillator circuit, has been adapted to improve the phase noise at a high tuning voltage by improving the loaded-Q performance. The improved radio frequency generation circuit 123 is illustrated in FIG. 4. The preferred mechanism proposes the use of an extra tuning capacitor to present sufficient phase noise performance at high tuning voltages, whilst the tuning circuit preserves start up oscillation condition criteria at lower tuning voltages. In this manner, the present invention solves the problem of lack of gain margin in a traditional Colpitts VCO configuration that would have resulted in oscillation start-up problems in the lower tuning voltage range. Notably, the main variable capacitor and the additional variable capacitor proposed in the preferred embodiment of the present invention use the same steering line of the loop filter.

The memory device 116 has also been adapted to include a look-up table storing appropriate tuning voltage levels to be applied to the main and additional tuning capacitor to produce a desired output frequency of the frequency generation circuit 123 of the wireless communication unit 100.

Of course, the various components within the wireless communication unit 100 may be realised in discrete or integrated component form. Furthermore, it is within the contemplation of the invention that the wireless communication unit 100 may be any wireless communication device, such as a portable or mobile PMR radio, a mobile

CM05224EI/DM/GB/Corse

- 9 -

phone, a personal digital assistant, a wireless laptop computer, etc.

Furthermore, although the preferred embodiment of the present invention is described with reference to a voltage controlled oscillator circuit design in a MS 100, it is envisaged that the inventive concepts herein described are equally applicable to any VCO design, for example one located in a base transceiver station (BTS).

1 0

The preferred mechanism for determining the key RF VCO parameter values is to use a 'loop gain' analysis method. The 'loop gain' analysis method is a practical tool for estimating, for example, the oscillation frequency, start up states and loaded-Q at the operating point.

1 5

The loaded-Q value can be estimated using the following relationship:

$$Q_{loaded} = f_{osc} \cdot \frac{d\theta}{df} \cdot \left(\frac{1}{2 \cdot \Phi_{rad}} \right) \quad [1]$$

2 0

Where:

θ = loop gain phase, and

Φ_{rad} = 57.3 degrees

2 5

The loop gain expression can be calculated using an analytical method, such as that described in "RF Oscillator Analysis and Design using Loop Gain method", authored by Noel Boutin and published in the trade journal "Applied Microwave and Wireless". Alternatively, numerical methods can be used, using simulation packages such as RF ADS Simulation. In this regard, the loop gain versus frequency and tuning voltage can be estimated by

3 0

CM05224EI/DM/GB/Corse

- 10 -

moving the ground, in FIG. 4, to the emitter port of the active device.

- In this regard, let us first define some of the terminology associated with VCO circuit designs. The loop gain is a complex function of frequency 'w'. The loop gain can be expressed by the two real functions of 'w', namely: $G(w)$, which is the magnitude function and $\phi(w)$, which is the phase of the loop gain function.
- These functions can be plotted as a function of 'w'.

$$H_{CL}(jw) = \frac{A_{OL}(jw)}{1 + \beta_{OL}(jw) \cdot A_{OL}(jw)}$$

$$\text{Loop Gain}(jw) = \beta_{OL}(jw) \cdot A_{OL}(jw) = G(w) \cdot e^{j\phi(w)} \quad [2]$$

Where:

- OL = Open Loop, and
CL = Closed Loop.

- Notably, it is important to determine the margin of gain and phase that is required to ensure oscillation of the VCO circuit. In this regard, so long as the gain of the VCO circuit and the phase-shift around the VCO circuit is maintained within the margin parameters, the circuit will oscillate.

- $\phi(w)|_{w=w_{OSC}} = 0$ will result in $G(w_{OSC}) = \text{Gain Margin}$ [3]
 $G(w)|_{w=w_{PM}} = 1$ will result in $\phi(w_{PM}) + 180 = \text{Phase Margin [Degrees]}$

Where:

OSC = Oscillation, and
PM = Phase Margin.

CM05224E1/DM/GB/Corse

- 11 -

In order to ensure oscillation based on a specific tuning voltage the gain margin should be greater than '1', and the phase margin '0'. Start-up parameters of the VCO circuit can be estimated using small signal analysis.

Referring now to FIG. 2, two graphs 200, 210 are shown illustrating the VCO loop gain (curved line m1) versus voltage using small signal analysis. The first graph 200 in FIG. 2 illustrates the estimation of the VCO loop gain in small signal mode. This analysis is performed in order to test whether the oscillator has sufficient loop gain for start up across all the tuning voltages. Using small signal analysis, it is shown that the gain margin m1 of the circuit of FIG. 4 is approximately 1.389, which indicates that the illustrated oscillator will oscillate at 828 MHz. The second graph 210 in FIG. 2 illustrates the estimation of the VCO loop gain in a large signal mode. The gain margin m1 in this case is less than -1.389 (noted using small signal analysis in a start-up mode) and is approximately '1' (1.009) at steady state.

Once the circuit has started to oscillate, the signal at the input to the transistor starts to build up, until the gain margin reaches a value of '1'. At that (steady state) stage the VCO circuit should be analysed using large signal simulation.

Applying Lesson's equation enables parameters such as loaded-Q, noise figure (NF) and power (at the input of the transistor 110) to be assessed against phase noise performance, as shown in equation [4] below. An increase in loaded-Q will result in more loss in the feedback, and less gain margin.

CM05224BI/DM/GB/Corse

- 12 -

$$\xi(f_m) = \frac{FR T}{2P} \left(1 + \frac{f^2}{4Q_L^2 f_m^2} \right)$$

[4]

5 The phase of the loop gain, as illustrated in the second graph 210 of FIG. 2, is shown plotted against oscillator loop frequency in graph 300 of FIG. 3. This plot in conjunction with Equation 1 is used to estimate loaded Q. In FIG. 3, m2 is a result for a gain of -9.720 recorded at loop frequency 770MHz and m4 is a result for a gain of 1 0 3.474 recorded at loop frequency 768MHz. The loaded-Q result obtained is 9.863. Using a large signal analysis, the oscillator gain margin should equal '1'. When trying to estimate loaded-Q using equation [1], it is important to look at the loop phase at a steady state condition, as 1 5 the loop phase value is different during the start-up rise time.

Thus, an accurate estimate of the loaded-Q cannot be performed just by using small signal analysis, as the 2 0 oscillator is yet to reach a steady state condition. This leads to the conclusion that the loaded-Q value should be estimated at the operating point, i.e. using large signal simulation with gain margin equal to '0'.

2 5 In order to illustrate the variation of loaded-Q degradation versus frequency, prior to implementing the inventive concepts of the present invention, an 800 MHz VCO, employing a 3 mm resonator was used in a Colpitts configuration. The tuning band of the VCO was configured 3 0 to be approximately 110 MHz, with the circuit analysed in a large signal mode. Table 1 illustrates the effect of a large tuning bandwidth over a degradation of loaded-Q.

CM05224EI/DM/GB/Corse

- 13 -

It is noteworthy that at high frequencies the gain margin increases with respect to frequency.

Table 1:

5

Tuning Voltage [v]	Oscillation Frequency [MHz]	Q Loaded	Gain Margin
0.5	771	9.8	1.256
1.5	796	8.9	1.296
2.5	828	8.1	1.336
3.5	861	7.45	1.349
4.5	902	6.95	1.351

Notably, the table values were estimated using a capacitance $C_x = 8\text{pF}$. By decreasing the capacitance value to approximately $C_x = 3\text{pF}$, it was noted that the loaded-Q value increased dramatically at high frequencies, up to the values of the low frequencies. However, such a low capacitance value inevitably resulted in a decrease in gain margin, which potentially leads to oscillation start up problems.

1 5

Thus, in accordance with the preferred embodiment of the present invention, it is proposed that a variable capacitance is introduced for C_x . By providing a variable capacitance for C_x , it is possible to attain a high capacitor value at small tuning voltages and a small capacitor value at high tuning voltages. Advantageously, this concept also results in a lower C_0 value, which will reduce main variable capacitor losses.

2 5

A preferred embodiment of the present invention is described with reference to a Colpitts VCO configuration. However, it is within the contemplation of the present invention that the inventive concepts described herein

CM05224EI/DM/GB/Corse

- 14 -

are equally applicable to other known VCO configurations, as would be appreciated by a person skilled in the art.

FIG. 4 illustrates a Colpitts VCO configuration 123, which has been adapted in accordance with the preferred embodiment of the present invention. The Colpitts Oscillator circuit is a 750 MHz - 870 MHz VCO circuit employing gain margin tuning. The feedback network of a Colpitts oscillator, i.e. the feedback from the emitter 460 to the base 465 of the transistor 450, comprises inductor L 440, and capacitors C1 420 and C2 410. The load resistor R_L 430 is connected to the collector port 455 by a large-value capacitor $C_{coupling}$ 435. The large-value capacitor $C_{coupling}$ 435 is strictly used only for dc isolation. A biasing resistor network is used to ensure the appropriate voltages are applied to the transistor ports, noting that resistor 470 is not by-passed and remains a part of the active circuit.

As the base port potential 465 is by-passed to the power supply, the transistor 450 can be considered as operating in a common base configuration. The collector signal is then fed back to the emitter port 460 through the tapped-capacitor C1 420 and C2 410 chain, as known in the art.

As known in the art, a voltage is applied to the steering line 405, sufficient to change/set the capacitance value of a main variable capacitance 425. The variation of the main variable capacitance 425, together with the other capacitance values of an input capacitance network, effectively determines the output frequency of the VCO circuit.

CM05224EI/DM/GB/Corse

- 15 -

In accordance with the preferred embodiment of the present invention, a second variable capacitance 415 has been introduced for C_x . By providing a second variable capacitance 415 for C_x , located between the resonator 475 and transistor base 465 it is possible to attain a high capacitor value at small tuning voltages and a small capacitor value at high tuning voltages.

Notably, a resonator 475 is used in the preferred embodiment of the present invention, in contrast to an inductor. In this regard, the gain margin tuning process described above can be applied, using the second variable capacitor 415 and notably the resonator 475 as the frequency of operation of the circuit can be more accurately predicted.

Notably, the preferred embodiment of the present invention uses a resonator in contrast to an inductor due primarily to the following:

- (i) The ability to provide a highly robust VCO design due to higher specification of resonator parameter accuracy; and
- (ii) Reduced component tolerances, leading to reduce VCO sensitivity.

2 5

The preferred design was based on a 2 mm MURATA™ resonator 475 with the following parameters:

- (i) Self-resonance frequency of 1350 MHz;
- (ii) A relative permittivity (ϵ_r) of 92;
- (iii) The additional (second) variable capacitor 415 from Infineon™ - BBY58_02W - was used; and

3 0

CM05224EI/DM/GB/Corse

- 16 -

(iv) The combination of the variable capacitance C_x and associated fixed capacitance C_c (hereinafter referred to as C3) was set between 18 pF to 6.8 pF

5 The desired performance was also based on the following parameters:

(i) Tuning range of 0.5 V - 4.5 V to support the oscillation band and tolerances;

(ii) Phase noise performance to be no worse than
1 0 -122 dBc/Hz @ 50 kHz offset, over the frequency band;

(iii) A supply voltage of 2.4 V;

(iv) $I_c \leq 5.6$ mA; and

(v) A requirement for the VCO to start oscillating at all tuning voltages, 0 V to 5 V.

1 5

Table 2: Wide Band Low Noise VCO Using Gain Margin Tuning

Wide Band Low Noise VCO Using Gain Margin Tuning

Parameter	Tuning Voltage [V]		
	0.5	2.5	4.5
C3_Modified [pF]	18	10	6.8
Frequency [MHz]	751	805	871
Phase Noise @ 12.5 kHz	-108	-106	-107
Phase Noise @ 25 kHz	-115.5	-115	-117
Phase Noise @ 50 kHz	-124	-122	-123.5
Phase Noise @ 100 kHz	-129.5	-128	-129
Phase Noise @ 250 kHz	-136.5	-137	-136.5

Thus, it can be seen that good VCO phase noise stability
2 0 can be attained over a wideband (15%) tuning frequency band using gain margin tuning, i.e. 0.5V to 4.5V applied to C3.

CM05224EI/DM/GB/Corse

- 17 -

In an enhanced embodiment of the present invention, the inductor 417 located on the VCO steering line is operably coupled to an additional digital-to-analogue converter (DAC). In this configuration, the inductor 417 is fed
5 using an independent DAC voltage. By applying a voltage to the additional variable capacitance in this manner, VCO sensitivity is improved.

Although the present invention has been described with
1 0 reference to a VCO operable over the TETRA UHF frequency band, i.e. the oscillator centre frequency following a divide-by-two function, it is envisaged that the inventive concepts described herein are equally
applicable for any wideband VCO design requiring high
1 5 phase noise performance. Clearly, for other wireless communication products, other circuit configurations may also be used, and the configuration and circuit component values illustrated in FIG. 4 are only a preferred example.

2 0 Furthermore, although the present invention has been described with reference to a Colpitts design, a skilled artisan will appreciate that the inventive concepts are equally applicable to other VCO designs. In particular,
2 5 it is envisaged that other circuit topographies can be used, for example, where the additional variable capacitor is not located on a transistor base, noting that the gain margin may change dramatically.

3 0 The present topography is based on a location and value of the resonator 475. The preferred location is substantially adjacent to the resonator 475. In this regard, the adjacent positioning of the second variable capacitance encompasses the second variable capacitance

CM05224EI/DM/GB/Corse

- 18 -

being located on the steering voltage line. Furthermore, the second variable capacitance is preferably located adjacent to the resonator 475, inasmuch as they are preferably both part of the VCO feedback network. In addition, the adjacent positioning of the second variable capacitance is preferably located between the resonator 450 and a base port of the active transistor device 450.

A skilled artisan would appreciate that alternative 'adjacent' locations of the second (additional) variable capacitance 415 with respect to the resonator 475 and the active device 450 may be used. In this regard, the term 'adjacent', when referring to the locations of two components, should not necessarily be solely considered as the two components being spatially or electrically positioned next to each other within the VCO circuit.

In addition, it is envisaged that integrated circuit manufacturers are able to manufacture integrated circuits to perform voltage controlled oscillator functions based on the new configuration, as hereinbefore described.

Additionally, the preferred embodiment of the present invention is illustrated with the active device being a bi-polar transistor. However, it is envisaged that a field-effect transistor arrangement will benefit equally from the inventive concepts described herein. Also, although the preferred range of C_x values is between 12 pF and 3 pF with a low tuning voltage range of 0.5V to 2.5V and a high tuning voltage range of 2.5V to 4.5V, a skilled artisan will appreciate that other values and other ranges can be used for different products and different frequency ranges.

CM05224EI/DM/GB/Corse

- 19 -

It will be understood that the VCO design enabling selection of a VCO operating frequency using a variable capacitance C_x as described above, provides either singly or in combination at least one or more of the following advantages:

(i) It enables a VCO design to operate over a wider bandwidth with the same tuning voltages, say around 15% of the VCO's centre frequency;

(ii) It provides an increase in loaded-Q at high tuning voltages, i.e. it provides better phase noise at those frequencies;

(iii) It provides an increase in gain margin at low frequencies, i.e. it ensures a minimum gain margin to provide sufficient oscillation thereby providing greater start-up confidence at low tuning voltages;

(iv) It provides a VCO design with reduced Main variable capacitor coupling; and

(v) It provides a more flexible design.

Whilst specific, and preferred, implementations of the present invention are described above, it is clear that one skilled in the art could readily apply variations and modifications of such inventive concepts.

Thus, a wireless communication unit, and a voltage controlled oscillator circuit have been provided where the disadvantages described with reference to prior art arrangements have been substantially alleviated.

CM05224EI/DM/GB/Corse

- 20 -

Claims

1. A wireless communication terminal (100) comprising a voltage controlled oscillator (123) including:
5 an active device (450) for producing a power gain;
a first variable capacitance (425), operably coupled to the active device (450), providing a variable capacitance value based on a voltage applied on a steering line; and
1 0 a feedback network comprising a resonator (475), operably coupled to an output of the active device (450), for feeding power back to an input of the active device (450) to sustain oscillations (123);
wherein a second variable capacitance (415) is operably
1 5 coupled to the steering line (405) and located adjacent to the resonator (475).
2. The wireless communication terminal (100) according to Claim 1, wherein the second variable
2 0 capacitance (415) is located between the resonator (475) and the active device (450).
3. The wireless communication terminal (100) according to Claim 1 or Claim 2, wherein the active
2 5 device (450) is a transistor, for example a Bi-polar transistor, the second variable capacitance (415) being located between the resonator (475) and the active device (450).
- 3 0 4. The wireless communication terminal (100) according to Claim 3, wherein the second variable capacitance (415) is located between the resonator (475) and a transistor base electrode (465).

CM05224EI/DM/GB/Corse

- 21 -

5. The wireless communication terminal (100) according to any one preceding Claim, further characterised by the second variable capacitance (415) being configured such that, when a high tuning voltage is applied, a loaded-Q value of the voltage controlled oscillator (123) is increased.

6. The wireless communication terminal (100) according to any one preceding Claim, further characterised by the second variable capacitance (415) being configured such that, when a low tuning voltage is applied, a gain margin of the voltage controlled oscillator (123) is increased sufficient to provide oscillations.

7. The wireless communication terminal (100) according to any one preceding Claim, further characterised by the second variable capacitance (415) providing a capacitance in a range of 12pF to 3pF.

8. The wireless communication terminal (100) according to any one preceding Claim, further characterised by a low tuning voltage applied to the steering line (405) being substantially in a range of 0V to 2.5V and a high tuning voltage applied to the steering line (405) being substantially in a range of 2.5V to 4.5V.

9. The wireless communication terminal (100) according to any one preceding Claim, further characterised by an inductor (417) located on the steering line (405) between the second variable capacitance (415) and a digital-to-analogue converter (DAC), such that an independent

CM05224EI/DM/GB/Corse

- 22 -

voltage can be applied from the DAC to the second variable capacitance (415).

10. The wireless communication terminal (100)
5 according to any one preceding Claim, further wherein the voltage controlled oscillator (123) comprises a Colpitts voltage controlled oscillator.

11. The wireless communication terminal (100)
1 0 according to any one of the preceding Claims, wherein the wireless communication terminal (100) is operable according to TETRA or GSM operational standards and is capable of generating radio frequency signals across two distinct TETRA or GSM operation frequency bands.

1 5
12. The wireless communication terminal (100)
according to any one of the preceding Claims, wherein the wireless communication terminal (100) is or is
incorporated in one of a portable or mobile radio, a
2 0 mobile phone, a personal digital assistant and a wireless capable laptop computer.

13. A voltage controlled oscillator circuit (123)
comprising:
2 5 an active device (450) for producing a power gain;
a first variable capacitance (425) operably
coupled to the active device (450) and providing a
variable capacitance value based on an applied steering
line voltage; and
3 0 a feedback network comprising a resonator (475),
operably coupled to an output of the active device (450),
for feeding power back to an input of the active device
to sustain oscillations (123);

CM05224EI/DM/GB/Corse

- 23 -

and a second variable capacitance (415) operably coupled to the steering line (405) and located adjacent to the resonator (475).

- 5 14. A wireless communication terminal (100) according to claim 1 and substantially as hereinbefore described with reference to, and/or as illustrated by, FIG. 1 of the accompanying drawings.
- 1 0 15. A voltage controlled oscillator circuit (123) according to claim 1 and substantially as hereinbefore described with reference to, and/or as illustrated by, FIG. 4 of the accompanying drawings.

CM05224EI/DM/GB/Corse

- 24 -

Abstract

WIRELESS COMMUNICATION UNIT AND WIDEBAND VOLTAGE
CONTROLLED OSCILLATOR THEREFOR

5

A wireless communication unit (100) comprises a voltage controlled oscillator (123) having an active device (450) operably coupled to a first variable capacitance (425) to provide a variable capacitance value based on an applied steering line voltage, and a feedback network comprising a resonator (475), operably coupled to an output of the active device, for feeding power back to an input of the active device to sustain oscillations (123). Notably, a second variable capacitance is operably coupled to the steering line (405) and located adjacent to the resonator (475).

The provision of a second variable capacitance located adjacent to the resonator enables a VCO design to operate over a wider bandwidth with the same tuning voltages, say around 15% of the VCO's centre frequency. This is achieved due to gain margin tuning applied to the resonator and second variable capacitor of the VCO circuit.

2 5

{FIG. 4 to accompany abstract}

THIS PAGE BLANK (USPTO)

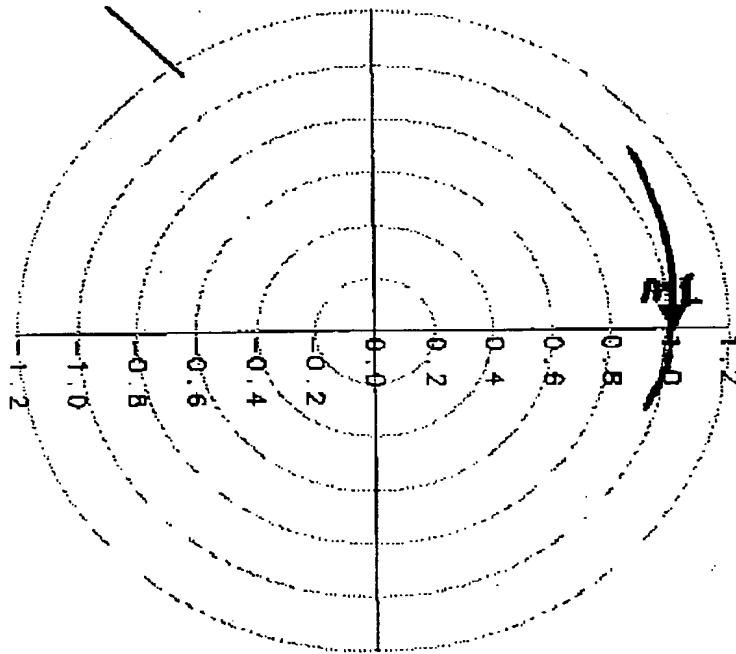
CM 05224

2/4

FIG. 2

210

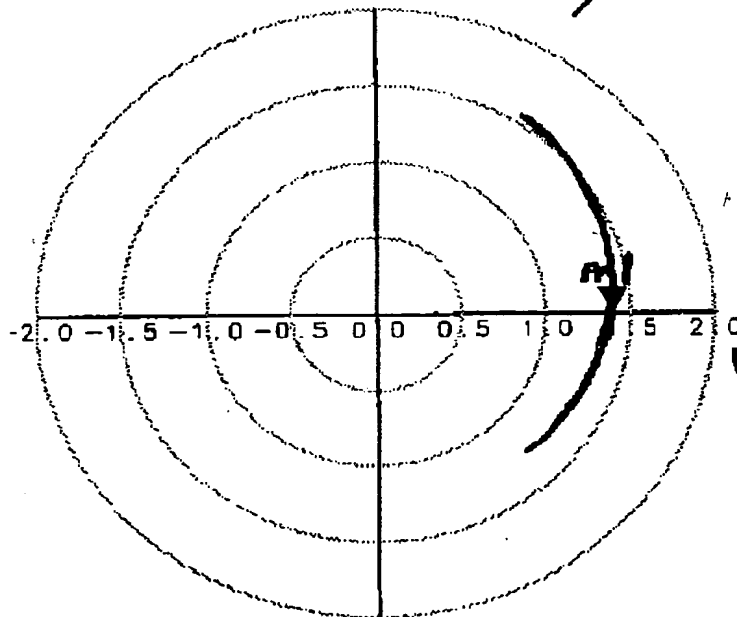
Loop Gain

FIG
2(a)

Voltage

200

Loop Gain

FIG
2(b)

Voltage

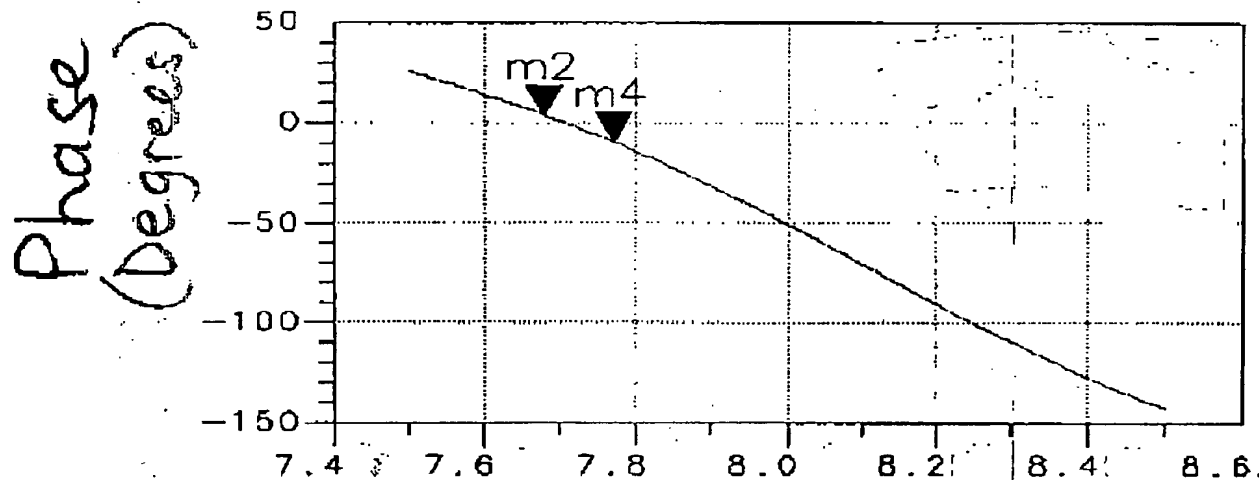
THIS PAGE BLANK (USPTO)

CMOS224E1

3/4

300

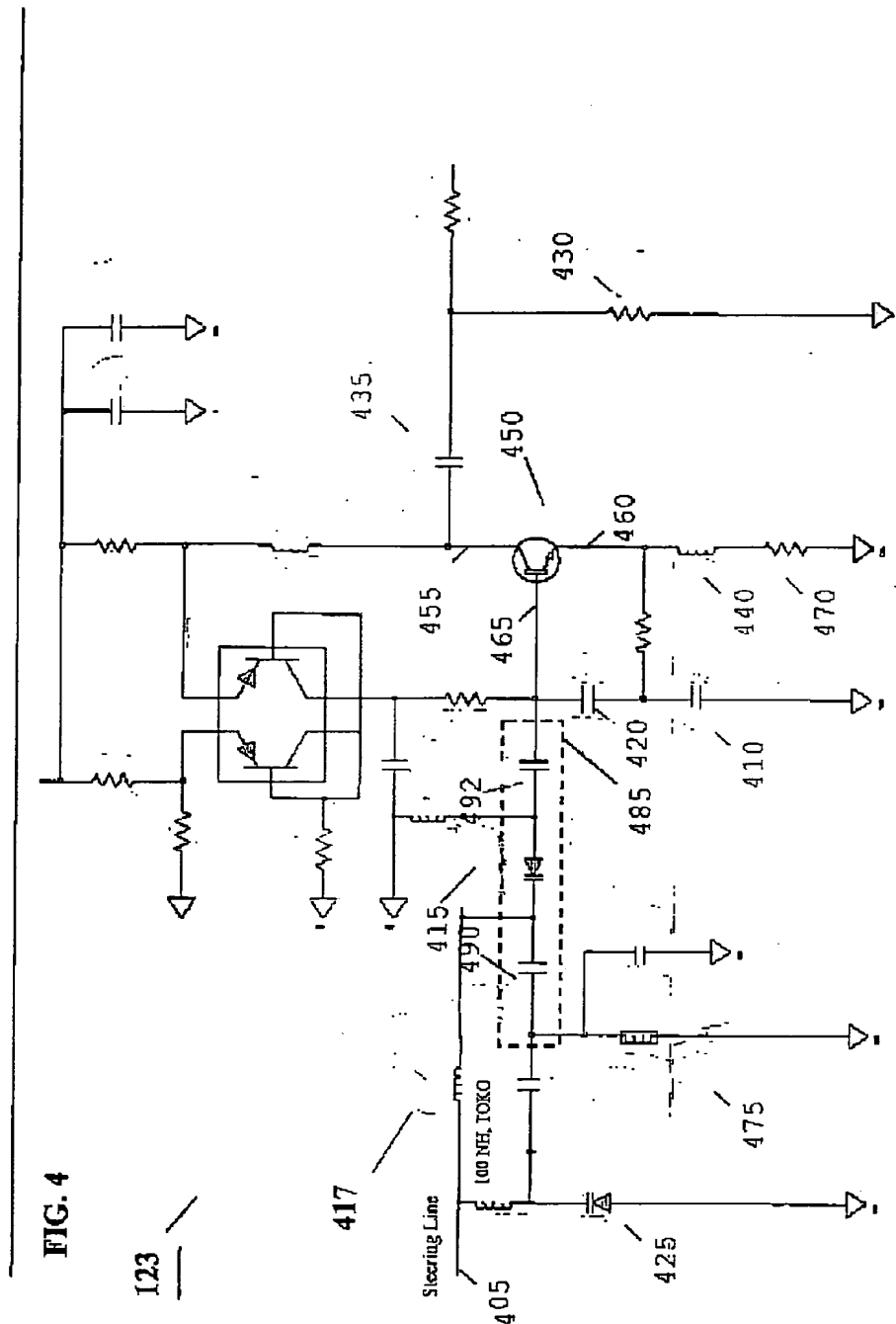
FIG 3





CM05224EI/DM/GB/Corse

CMO5224E1
4/4



THIS PAGE BLANK (USPTO)